A High-Power Dual-Directional Coupler

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A dual-directional loop coupler in WR 430 waveguide has been installed at DSS 14 as part of the system to measure station range delay. This installation was necessary to provide special test translator signal injection ports for the Voyager near-earth calibration sequence, which required that the SPD maser be bypassed to prevent saturation of the receivers. The design of the dual coupler and testing of this device at high power is discussed.

I. Introduction

During the Voyager near-Earth calibration sequence, the received power levels at the traveling wave maser (TWM) inputs are high enough to saturate the station receivers, and the high-power uplink can saturate the spacecraft receiver. A solution to this problem is to bypass the klystron, i.e., use the exciter only, and to bypass both the S-band TWM and the X-band TWM. All equipment to accomplish this, including the coupler under discussion, was installed at DSS 14 during the recent update period for Voyager. The X-band bypass is achieved by turning off one of the two K-band pumps, which reduces the TWM gain by approximately 45 dB. The S-band TWM is bypassed by means of waveguide switches.

In this configuration, means must be provided to inject a sufficient test translator signal level for range delay precals. This is accomplished at X-band by removing attenuation in the test translator signal path to the TWM. For S-band, a dual-directional WR-430 waveguide coupler is used. This article describes the coupler and the test results.

II. Description and Testing

Figure 1 shows the S-band polarization diversity (SPD) cone waveguide configuration and the location of the coupler. Figure 2 is a block diagram of the system prior to installation of the bypass equipment. As is evident from Figs. 1 and 2, there is no simple waveguide section near the feed horn that could be replaced by the new coupler. It was decided that the matching section (Fig. 3) could be replaced with a new matching section incorporating two identical compact loop couplers of 54 dB each. A coupling value of 54 dB was specified for the sampling port because the previous sampling port was this value (Fig. 2), which provides an appropriate signal level. The test translator injection port coupling value was also made 54 dB because, at 400 kW, the power coupled out is at a tolerable receiver system input level (approximately 1.6 W for 54 dB as compared to 40 W for 40 dB coupling value).

Various coupler designs were considered. A dual cross guide coupler could be made to fit the available space, but is difficult or impossible to water-cool at high power levels. Other coupler designs such as broadwall and sidewall couplers are too large physically. A loop coupler was considered the most promising type for this purpose, because of its compactness and good electrical characteristics. Previous experience with this design (SLU cone-1973) indicated that sufficient directivity, bandwidth, and stability were possible.

A single coupler test model was designed and fabricated by Maury Microwave Corp. (MMC) (Figs. 4-7). The photographs show the loop coupler module and its installation in the waveguide section. This unit was checked electrically by MMC before delivery (see test report, Appendix A). The coupler was then tested at the Microwave Test Facility at Goldstone to verify operation at 400 kW. Test results (Appendix B) show deterioration of the test coupler due to resistive termination burnout at high power. It was not designed to withstand 40 W. The initial coupling value was 40 dB, but later changed to 54 dB. The test results for the 40-dB coupling value, however, did prove that the waveguide main line suffered no degradation due to arcing or overheating. There had been some doubt that the device would pass the high power test, because the coupling loops appear to present appreciable discontinuities in the waveguide walls (Fig. 6).

The final design dual coupler was fitted with two 54-dB modules (Fig. 8 and Appendix C) and tested at 400 kW. The test of this unit was more difficult than that of the test coupler since the dual coupler assembly included the normal matching posts needed to tune out reflections of the feed horn orthomode transducer structure. An external tuning device was used to improve the VSWR of the dual coupler assembly in the test system. The test report is given in Appendix D.

This unit was installed in the SPD cone at DSS 14 and has since been used as part of the range delay calibration system. Figure 9 is a simplified block diagram of the Block 4 test translator method utilizing the dual coupler. The 2113-MHz signal is derived from the transmitted power (usually 10 to 20 kW) through port 1 of the dual coupler. The 2295-MHz signal from the test translator is injected into the receiving system through port 2. Two coaxial isolators were added to the 2295-MHz translator path to prevent 2113-MHz signal from entering this line and reflecting back to cause a multipath effect.

This configuration has advantages other than its use in the TWM bypass mode. Injection of the test translator signal is at a point as near the feed horn as possible, allowing direct range delay measurement of all parts of the system below the feed horn at this one point. In the old configuration (Fig. 2 and Ref. 1), some of the component delays below the feed horn had to be calculated or precalibrated before installation into the system. The range delay for each TWM system was measured separately at its respective input port. Reference 2 describes in more detail the advantages of this configuration for station delay calibration.

III. Conclusion

During the Voyager I near-Earth ranging sequence, DOY 254-256, 1977, this system was successfully used as planned to calibrate the station delay. Successful operation of the described calibrating system indicates that the installation of the dual coupler should be made permanent, not only at DSS 14 but at other stations as well.

Acknowledgment

The authors express their thanks to M. A. Gregg and personnel of the Microwave Test Facility, Section 333, for testing these components at high power.

References

1. Otoshi, T. Y., et al., "Calibration of Block 4 Translator Path Delays at DSS 14 and CTA 21," *DSN Progress Report 42-37*, p. 188, Jet Propulsion Laboratory, Pasadena, Calif.

2. Otoshi, T. Y., Wallace, K. B., and Lyon, R. B., "Dual Coupler Configuration at DSS 14 for the Voyager Era," *DSN Progress Report 42-42* (this issue).

Appendix A

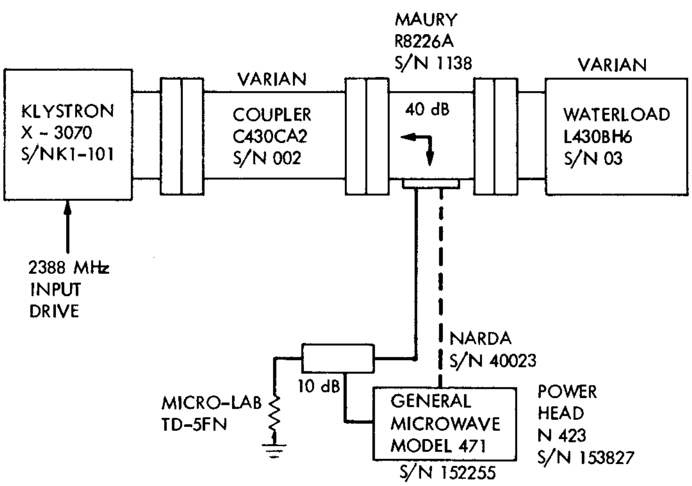
Maury Microwave Corporation Test Report on 40-dB Test Model Loop Coupler Assembly

Frequency, MHz	Coupling	VSWR, primary	VSWR, sec	Directivity
2.245	39.5	1.01	1.11	20.0
2.285	39.5	1.01	1.11	20.4
2.325	39.4	1.01	1.10	20.8

Appendix B

Test Report on 40-dB Loop Coupler Assembly High Power Test (From M. Gregg JPL Internal Report)

The following test setup was made to test the Maury microwave coupler model R 8226A, S/N 1138, for operations at 400 kW. The following data was taken as the power was increased in steps to obtain the 400-kW operation.



Time	Pwr out, kW	T WL °C	WL flow, gpm	Temp coupler	Pwr meter, dB
Test set 1, pwr meter direct to test coupler					
7:30	10.2	0.381	100	Cool	11.5
7:45	20.3	0.77	100	Cool	14.3
8:00	20.3	0.77	100	Cool	13.7
8:00	50.8	1.926	100	Cool	17.8
8:15	50.6	1.92	100	Warm	17.1
8:15	100.1	3.80	100	Warm	23.1
8:30	100.1	3.80	100	43°C	22.7
8:30	200.1	7.58	100		32.0
8:45	200.1	7.58	100	54°C	38.2
Test set 2 installed 10-dB coupler and load					
8:46	200.6	7.60	100		27.6
8:50	100.1	3.80	100		24.6
9:30	200.6	7.60	100	54°C	27.6
9:30	301	11.40	100		29.5
9:35	301	11.40	100	60°C	29.5
9:45	301	11.40	100	66°C	29.5
10:00	401	15.2	100	71°C	30.0
10:30	401	15.2	100	77°C	29.9
11:00	401	15.2	100	77°C	29.9
11:30	401	15.2	100	77°C	29.9
System turned off					
12:40	401	15.2	100		30.0
12:45	401	15.2	100		20.9
12:46	401				34.2
12:48	401				31.2
13:18	401	15.2	100		31.1

It can be noted in the data that at 200 kW the coupler output changed from 32.0 dB to 38.2 dB when the 10-dB coupler and load was installed in the output and the reference taken at 200 kW. The system power was then reduced to 100 kW and reference taken as noted in the data. With the system off for over an hour the temperature of the coupler was allowed to return to room temperature.

The system was then brought to 400 kW directly, without any warmup time. The coupler output went from 32.0 to 20.9 dB in the space of 5 min and then raised to an output of 34.2 dB within the next 3 min. It settled to an output of 31.1 dB after 30 min.

The cycle was again repeated and the radical changes seen at the early time were not noted. The coupler had a steady output of 31.1 ± 0.1 dB at 401 kW. The Narda coupler calibrated at 2388 Mhz = 9.9 dB.

Appendix C

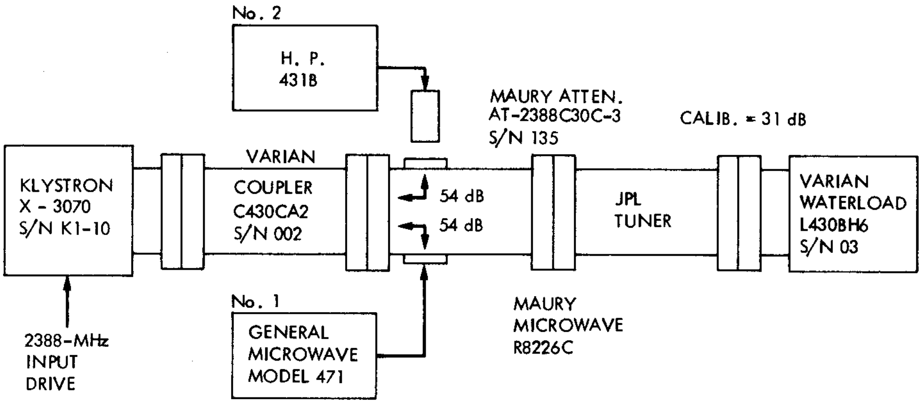
Maury Microwave Corporation Test Report on 54-dB Dual Coupler Assembly

1 Port					2 Port				
Frequency,	Coupling	VSWR	Directivity	Main line VSWR	Frequency,	Coupling	VSWR	Directivity	Main line VSWR
2093	53.8				2093	54.3			
2113	53.9	1.10	20.6	1.30	2113	54.4	1.12	20.6	
2133	59.0				2133	54.4			
2275	53.5				2275	53.8			
2295	53.1	1.09	23.9	1.34	2295	53.5	1.15	25.0	
2315	53.2				2315	53.6			

Appendix D

Test Report on 54-dB Dual Loop Coupler Assembly High Power Test (From M. Gregg JPL Internal Report)

The following test setup was made to test the Maury microwave coupler model R 8226C, S/N 1160, for operations at 400 kW. The following data was taken as the power was increased in steps to obtain the 400-kW operation. The VSWR of tuner and coupler = 1.09, flow waveguide = 2 gpm.



Time	Pwr out, kW	Refl pwr, kW	Sys H_2O Temp, °C	ΔT °C	WL flow, GPM	Coupler temp.	No. 1 pwr mtr, dB	No. 2 pwr mtr, dB
8:45	50	0.15	28.9	1.9	98	Cool	22.8	22.8
9:00	50	0.14	35.6	1.9	98	Cool	22.6	22.2
9:00	100	0.26	31.6	3.85	98	Luke warm	26.0•	26.2
9:15	100	0.275	29.6	3.86	98	Luke warm	26.0	26.3
9:15	150	0.38	29.5	5.8	98	Warm	27.8	28.2
9:30	150	0.39	30.4	5.8	98	Warm	27.7	28.2
9:30	200	0.49	30.5	7.75	98	Warm	29.1	29.5
9:45	200	0.50	32.0	7.75	98	Warm	29.1	29.6
9:45	250	0.59	32.2	9.68	98	Warm	30.2	30.7
10:00	250	0.62	33.7	9.68	98	Warmer	30.2	30.7
10:00	300	0.72	33.9	11.6	98	Warmer	30.9	31.1
10:15	300	0.74	35.0	11.6	98	Warmer	30.9	31.1
10:15	350	0.87	35.3	13.55	98	Warmer	31.6	31.8
10:30	350	0.90	36.7	13.55	98	43°C	31.6	31.8
10:30	395	1.03	37.2	15.3	98	43°C	32.1	32.3
10:40	400	1.1	38.1	15.46	98	49°C	32.2	32.4
11:00	400	1.16	38.9	15.46	98	49°C	32.1	32.4
11:15	400	1.17	38.8	15.46	98	49°C	32.1	32.4
11:30	400	1.17	39.2	15.46	98	49°C	32.1	32.4
11:45	400	1.19	39.8	15.46	98	49°C	32.1	32.4

The RF and beam were turned off, with water on system, which allowed the system to stabilize to normal temperature of 28.5°C. The system was then brought directly to 400 kW and the following data was then taken:

12:50	400	0.8	34.9	15.5	98	Warm	32.5	32.3
01:20	400	1.1	39.5	15.5	98	–	32.1	32.3

At no time during the test were any arcings or kickoffs experienced; the only thing noted was some jitter in the reflected power monitor.

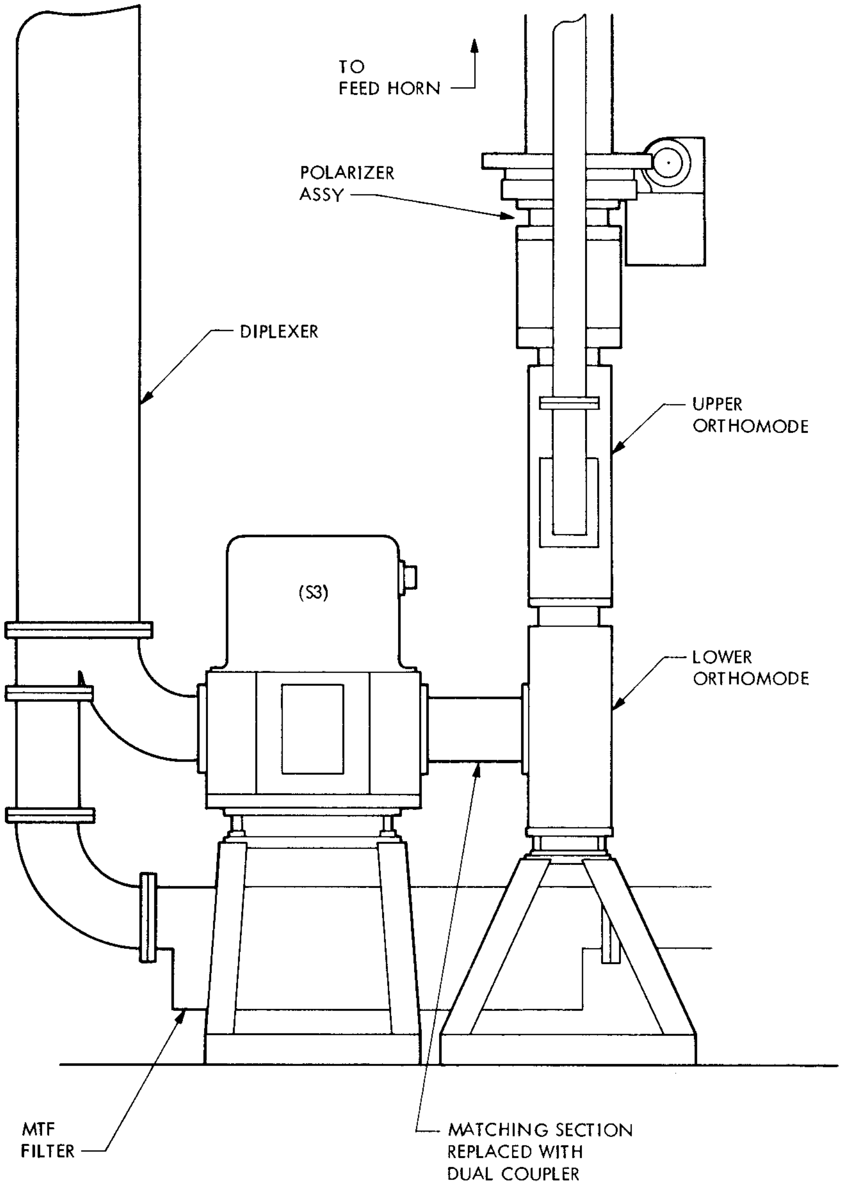


Fig. 1. Dual coupler location in SPD cone waveguide system

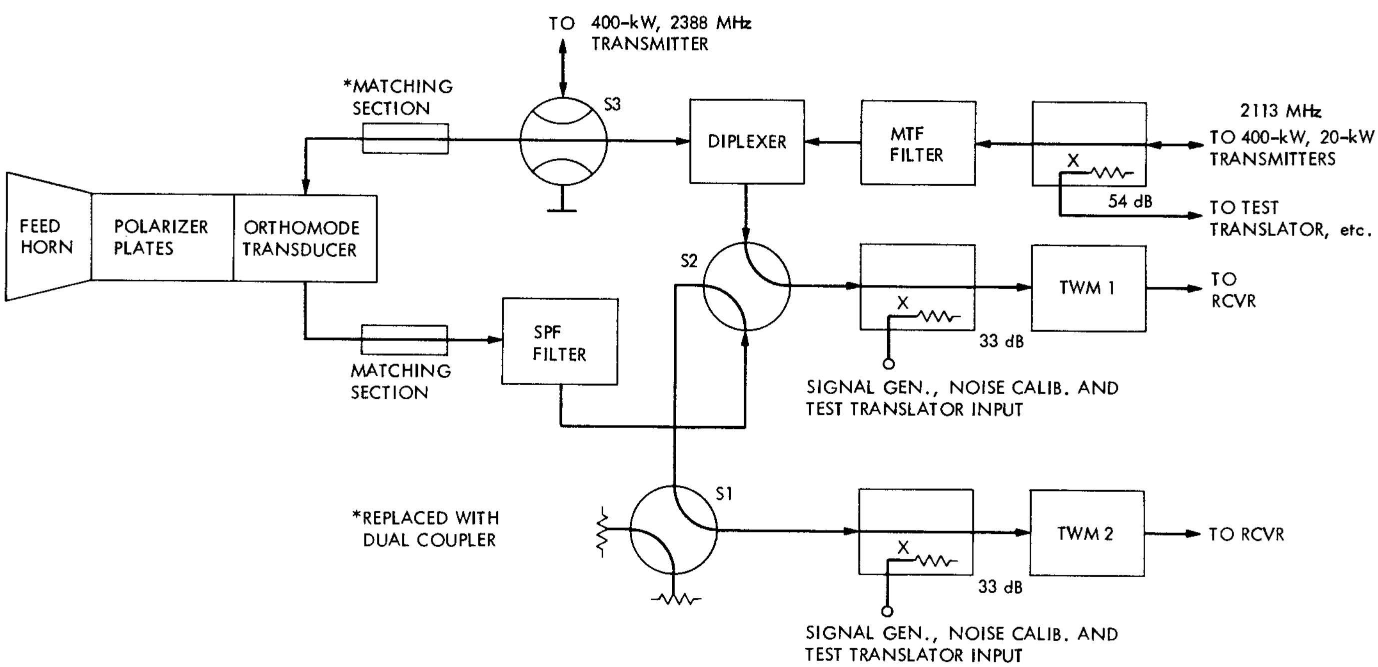


Fig. 2. Simplified block diagram of S-band microwave system at DSS 14

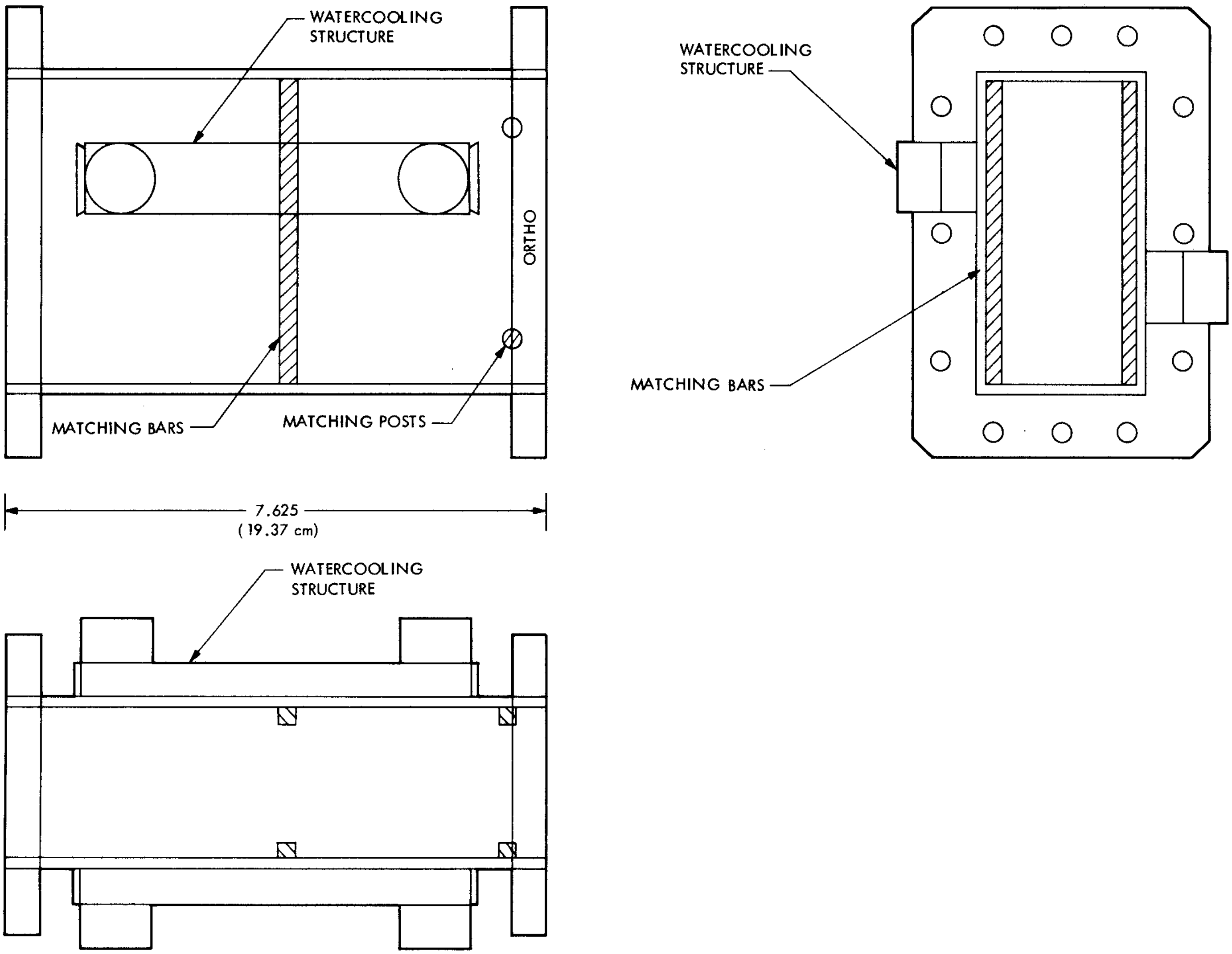


Fig. 3. Waveguide matching section for lower orthomode transducer

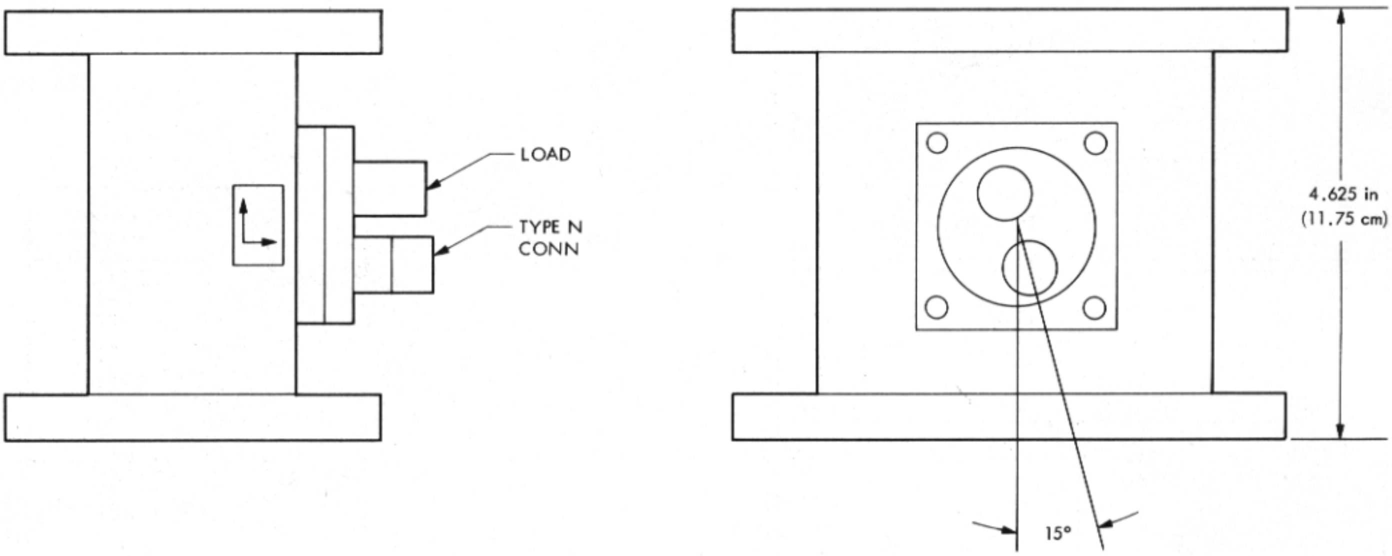


Fig. 4. 40-dB test model loop coupler drawing

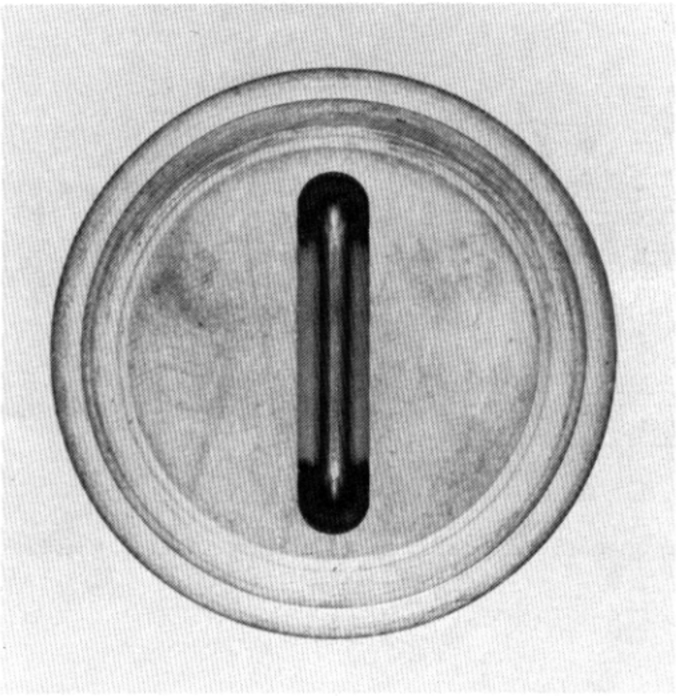


Fig. 5. 40-dB loop coupler module

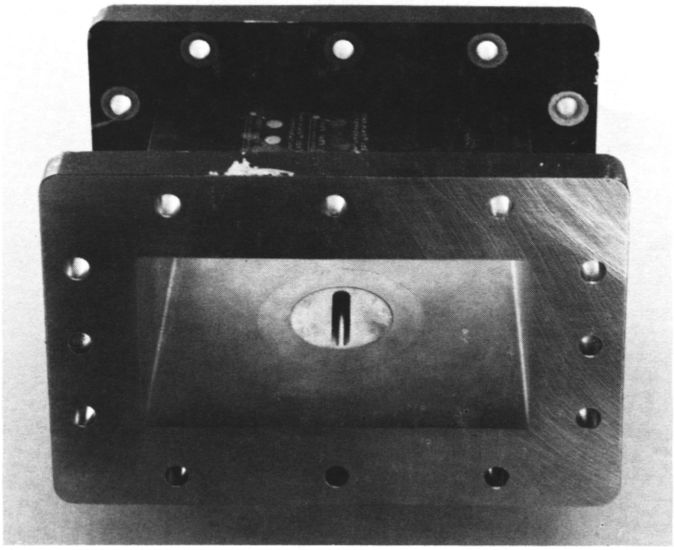


Fig. 6. 40-dB loop coupler module inserted into WR 430 section (internal view)

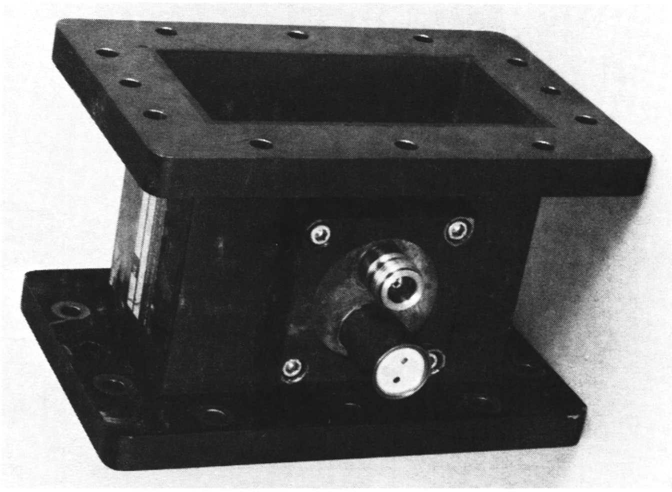


Fig. 7. 40-dB loop coupler module inserted into WR 430 section (external view)

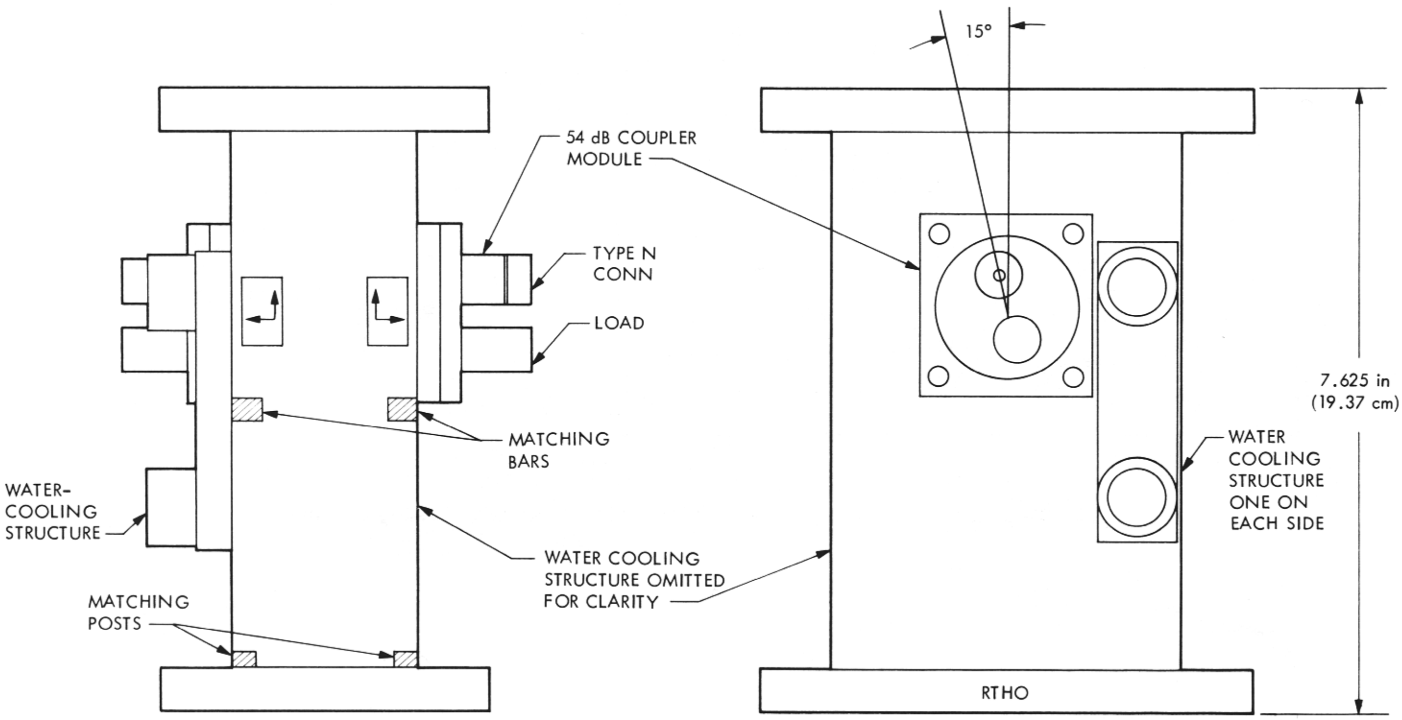


Fig. 8. 54-dB dual loop directional coupler assembly (with waveguide matching section and water cooling plumbing)

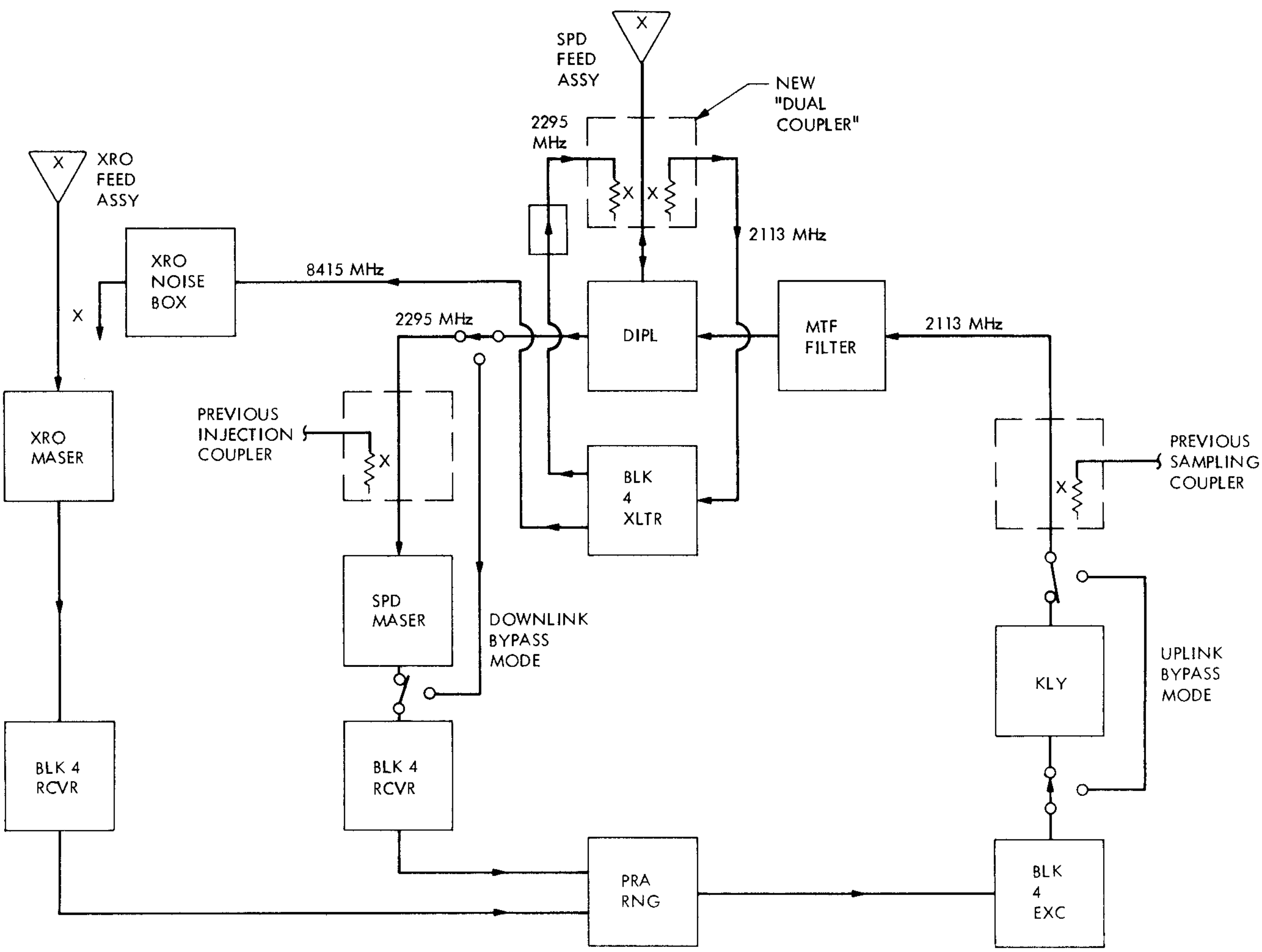


Fig. 9. Simplified block diagram of dual coupler DSS 14 range calibrating configuration